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Influence of Influent CN Ratio on N_2O Release and Its Reduction Control in Sewage Biological Denitrification

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Abstract

At present, the problem of eutrophication of water bodies is becoming more and more prominent, and the technology of biological denitrification of sewage has been developed rapidly, but N20 will be produced in this process. N20 is an important greenhouse gas. Its greenhouse effect is 310 times that of CO:, and it continues to grow at a rate of 0.25% per year. It has an important impact on the global environment and climate change. N20 can also deplete ozone, destroy the ozone layer, seriously affect the natural ecosystem and threaten human survival. Studies have shown that biological denitrification of sewage is an important man-made source of N20 release. It is of great significance to study the pollutant removal effect and N20 release in the sewage biological denitrification system. Different sewage treatment processes will cause different amounts of nitrous oxide emissions. Controlling the inflow method is an effective way to reduce nitrous oxide emissions: at the same time, temperature, ammonia oxidation rate, and dissolved oxygen concentration will all affect the amount of nitrous oxide. The emissions of dinitrogen have a more obvious impact. It is possible to reduce the emission of nitrous oxide and reduce the impact of nitrous oxide on the greenhouse effect by selecting the sewage treatment process with less nitrous oxide emission and controlling the process operating parameters.

***Keywords**: Sewage biological denitrification, influent carbon to nitrogen ratio, N2O, molecular biology, operating conditions*

I. Overview of The Development of Wastewater Biological Denitrification Process

Excessive levels of nitrogen and phosphorus are the main factors that cause eutrophication of water bodies. In our country's water environment system, nitrogen and phosphorus pollution is very serious[1]. Traditional denitrification methods can be divided into physical and chemical methods and biological methods. The physical and chemical methods mainly include: purge method, selective ion exchange, breakpoint chlorination, electrodialysis and reverse osmosis, magnesium ammonium phosphate precipitation and chemical coagulation. Biological method is mainly composed of nitrification process and denitrification process. Among them, the physical and chemical method has high processing costs and operating costs, is likely to cause secondary pollution, and usually can only remove ammonia nitrogen, and is mostly used in the pretreatment of high-concentration industrial wastewater. The biological denitrification technology that achieves biological denitrification through microbial nitrification and denitrification has been rapidly developed and widely used in recent years[2].

1.1 Development background of wastewater biological denitrification process

Sewage biological denitrification technology is an economic and effective treatment technology proposed by the

United States, South Africa and other countries in the mid-1970s[3]. In foreign countries, countries have increasingly strict requirements on the denitrification effect of wastewater. In the decree on wastewater treatment issued by the European Community in 1991, in addition to the strict quantification of COD, BOD and SS in the effluent of wastewater treatment plants, it also Strict regulations shall be made on the nitrogen and phosphorus in the effluent from water bodies that will undergo eutrophication or be used as water sources. In our country, the research work of sewage biological denitrification technology started in the 1980s and has developed rapidly in the past 20 years[4-6]. However, due to the worsening situation of environmental pollution, my country has repeatedly issued detailed laws and regulations on sewage discharge and effluent from municipal sewage treatment plants. The "Urban Wastewater Treatment and Pollution Prevention Technology Policy" promulgated and implemented in 2020 clearly stipulates: The establishment of cities, key river basins and water resources protection areas in the establishment of towns must build secondary sewage treatment facilities, which can be implemented in phases and batches. Acceptance When the water body is a closed or semi-closed water body, in order to prevent eutrophication, urban sewage should undergo secondary intensive treatment to enhance the effect of phosphorus and nitrogen removal." Therefore, sewage biological nitrogen removal technology has become an important research direction in my country[7-10].

1.2 Biological principles of biological denitrification of sewage

There are three groups of bacteria that are mainly involved in the biological denitrification process:

（1）Ammonifying bacteria, organic nitrogen compounds in sewage are decomposed under the action of ammonifying bacteria to undergo denitrification and are converted into ammoniacal nitrogen. The reaction formula is:

$$\mathbf{RCHNH_2COOH + O_2 \rightarrow RCH(OH)COOH + CO_2 + NH_3}$$

（2）Ammonia oxidizing bacteria and nitrite oxidizing bacteria convert NH4+ to N03- under aerobic conditions, and nitrification occurs. First, ammonia oxidizing bacteria (oxidize NH4+ to NO2-, and then nitrite oxidizing bacteria, nitrite oxidizing bacteria, oxidize N02 to N03-. Among them, the nitrification caused by autotrophic microorganisms is called autotrophic nitrification; The nitrification caused by heterotrophic microorganisms is called heterotrophic nitrification[11].

The first stage reaction formula of the nitration reaction is:

$$\mathbf{55NH_4^+ + 76O_2 + 109HCOO^- \rightarrow C_5H_7NO_2 + 54NO_2^- + 57H_2O + 104H_2CO_3}$$

The reaction formula of the second stage of the nitration reaction is:

$$\mathbf{400NO_2^{\circ} + NH_4^+ + 4H_2CO_3 + 195O_2 \rightarrow C_5H_7NO_2 + 3H_2O + 400NO_3^-}$$

The total reaction formula of the total nitration reaction is:

$$\mathbf{NH_4^+ + 1.83O_2 + 1.98HCO_3^- \rightarrow 0.021C_5H_7NO_2 + 1.041H_2O + 1.88H_2CO_3 + 0.98NO_3^-}$$

From a biochemical level, nitrification is far from simple, involving a variety of metabolic pathways catalyzed by enzymes. Ammonia nitrogen is oxidized to NH2OH and H2O under the action of ammonia monooxygenase (AMO); NH20H is oxidized to NO2 by aminoreductase; and it is oxidized to NO3 under the action of nitrite oxidoreductase (NOR). This process is accompanied by a complex transformation of matter and energy[12]. After nitrification, ammonia is converted into nitrite and nitrate, which increases its mobility, is easily absorbed by plants, and is also easily lost with water[13-15].

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（3）Denitrifying bacteria. Under anaerobic or hypoxic conditions, nitrogen oxides (NO2- and N03-) as electron acceptors are reduced by denitrifying bacteria to cause denitrification. Among them, denitrifying bacteria reduce nitrogen oxides (NO2 and N03-) to NH3-N, and the process for cell synthesis is called assimilation nitrate reduction; denitrifying bacteria reduce nitrogen oxides (N02- and N03-) to The gaseous substances such as NO, N2O and N2 are called dissimilation nitrate reduction, which is also called biological denitrification process. Denitrifying bacteria are different from nitrifying bacteria. They have no specific taxonomic groups, and are polydisperse and prokaryotic in many genera. The reaction formula is:

$$6NO_3 + 5CH_3OH \rightarrow 5CO_2 + 3N_2 \uparrow + 7H_2O + 6OH^-$$

Most denitrifying bacteria are heterotrophic facultative anaerobic bacteria, which can use a variety of organic matter as electron donors in the denitrification process, including carbohydrates, organic acids, alcohols, etc., to generate nitrogen to achieve biological denitrification purposes . Therefore, in sewage treatment, a certain amount of organic compounds can be added to the denitrification tank[16].

1.3 Types of sewage biological denitrification process

1.3.1 Bardenpho denitrification process
The predecessor of the Bardenph denitrification process was a three-stage activated sludge process in which ammoniation, nitrification, and denitrification were carried out in their respective reactors. Although it is conducive to the cultivation of the dominant flora, due to the high engineering cost and inconvenience of management, it has been further improved to a two-stage biological denitrification system (the first-stage aeration tank and the second-stage aeration tank are combined), namely Bardenph. Denitrification process[17]. Its function is mainly to remove organic matter and oxidize organic nitrogen; in the nitrification tank, ammonia nitrogen is oxidized into nitrous nitrogen and nitrate nitrogen; in the denitrification tank, nitrite nitrogen and nitrite nitrogen are converted into gaseous nitrogen and escape from the water. This process has very good denitrification and organic removal effects, but because of its long process, there are many structures and high capital construction costs. In addition, the operating cost of additional carbon sources is relatively high, and there are few applications at present[12-20].

1.3.2 A/O process
The A/O (anoxic/aerobic) denitrification process is also known as the pre-denitrification biological denitrification process, which is currently a more widely used process. The characteristic of the process is that the raw water first enters the anoxic tank and the reflux liquid of the aerobic tank is mixed, and the organic matter in the raw water is used as a carbon source to cause a denitrification reaction. There is only one sludge system in the entire A/O process, in which heterotrophic bacteria, denitrifying bacteria and nitrifying bacteria that degrade organic matter coexist[21]. They circulate in anoxic and aerobic environments, and act separately under their adapted conditions. Compared with the Bardenpho denitrification process, the A/O process is simpler, which can greatly reduce the capital investment cost, and can use the organic matter in the raw water as a carbon source without additional addition, thus reducing the operating cost. The nitrification liquid cannot be completely returned to the anoxic reactor, and the AIO biological denitrification process cannot achieve complete denitrification, and some of it will be directly discharged with water[22].

1.3.3 Oxidation ditch process
Oxidation ditch process, also known as circulating aeration tank, is a biological sewage treatment technology developed by Pasveer in the Netherlands in the 1950s, which is a modification of the activated sludge process. The characteristic is that the mixed liquid continuously circulates in the closed ditch and the sludge load is low. Its low load and long sludge age are very suitable for the growth of nitrifying bacteria[23]. Therefore, in the oxidation ditch process, the organic matter has a good removal effect, and the operation is simple, and the infrastructure and operation are lower than the activated sludge method, which is a more economical and effective sewage treatment

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technology. Although this process has the advantages of good effluent water quality, strong impact load resistance, high phosphorus and nitrogen removal efficiency, easy sludge stability, low energy consumption, and easy automatic control. However, in the actual operation process, there are still a series of problems: such as uneven flow velocity and sludge deposition problems.

1.3.4 SBR process

Intermittent activated sludge treatment system, also known as sequential batch activated sludge treatment system. SBR process

(Sequencing Batch Reactor) has multiple functions such as regulation, aerobic (anoxic) reaction, precipitation and so on[24].

A working cycle of the SBR process is divided into five stages: water inlet period, reaction period, sedimentation period, drainage and sludge discharge period and idle period[25]. In a working cycle, the operating time, sludge concentration and operating status of each stage can be flexibly adjusted according to the water quality of the raw water, the effluent water quality requirements and the operating function requirements. The SBR process has the unity of space and can only be effectively controlled in time, and its operation is very flexible. The nitrification-denitrification principle of the SBR reactor and the continuous flow reactor has the same denitrification principle. The difference is that the nitrification and denitrification of the continuous flow reactor are realized in space, while the SBR realizes the control in the same reactor in terms of time. The length of aerobic reaction and anoxic reaction, the final denitrification efficiency can reach more than 90%[26].

Compared with the continuous activated sludge process system, the SBR process composition is relatively simple. The SBR process is a very competitive technology with the following characteristics: (1) In most cases (including industrial wastewater), there is no need to set up a regulating tank, and it has strong impact load resistance. (2) Sludge volume index (SVI) is low, sludge is easy to settle, and sludge bulking is not easy to occur. (3) The denitrification and dephosphorization reactions can be carried out in a single aeration tank. (4) The use of solenoid valves, automatic timers, liquid level gauges and programmable controllers and other automatic control devices can achieve full automation and be controlled by the central control room. (5) The reaction impetus is large, the operation management is proper, and the treated water quality is due to continuous flow. (6) There is no need for sludge return equipment and secondary sedimentation tanks, and the volume of the aeration tank is also small, so the construction investment and operating costs are low.

II. Release Of N2o in the Biological Denitrification Process of Sewage

The previous part mentioned the estimated annual N2O release amount and release situation in the sewage treatment process for the world. Studies have pointed out that 90% of the nitrogen may be converted into N2O released in the laboratory-scale wastewater denitrification process, while 14.6% of the nitrogen may be converted into N2O released during the actual-scale wastewater denitrification process. Scientists from various countries have carried out research on the release of N2O in different sewage treatment plants and found that the differences are very large, which may be caused by factors such as location, treatment technology, and facility scale. In China, the research on the release of N2O is mostly concentrated on the laboratory scale, and further research is needed to explore the detailed mechanism of its release[27].

2.1 The release mechanism of N20 in the biological denitrification process of sewage

The main processes of sewage biological denitrification are nitrification and denitrification. It is generally considered that N20 is the product of incomplete nitrification or incomplete denitrification.

(1) Nitrification

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Nitrification is mostly involved in inorganic autotrophic microorganisms, and it mainly includes two steps: First, ammoniating bacteria convert ammonia nitrogen into nitrite under the action of ammonia monooxygenase (AMO) and light amine oxidoreductase (HAO). In this process, in order to avoid the accumulation of nitrite nitrogen in the cells, heterogeneous nitrite reductase will be produced at the same time, thereby using nitrite as the electron acceptor to produce N20, but this process only occurs when the nitrite nitrogen accumulates to a large extent. It only occurs at high concentrations. There are many factors that cause the accumulation of nitrite nitrogen[28]. Yao Kuowei et al. believe that the oxygen saturation constant of ammonia oxidizing bacteria is 0.20-0.40 mg/L, and the oxygen saturation constant of nitrite oxidizing bacteria is 1.2-1.5 mg/L, so it is low. The concentration of DO will lead to the accumulation of nitrite; the generation cycle of ammonia oxidizing bacteria is shorter than that of nitrite oxidizing bacteria, prompting the elimination of nitrite oxidizing bacteria, leading to the accumulation of nitrite and producing N2O. In addition, Wrage et al. believe that N20 may also be produced by the denitrification course of nitrifying bacteria, which reduces nitrite nitrogen to NO and N2O. Some scholars have discovered the existence of heterotrophic nitrifying bacteria, confirming that the heterotrophic nitrification process also produces N2O.
(2) Denitrification

The denitrification process is a biochemical process completed by a group of heterotrophic microorganisms (denitrifying bacteria) under anoxic or anaerobic conditions. Unlike nitrification, N2O is an intermediate product of denitrification. Molecular biology and cell biology studies have determined that the denitrification process consists of 4 stages. Because NO is highly toxic, it is difficult for bacteria to survive with NO as the final product, so the products are usually N2O and N[29]. There are four main enzymes that catalyze this process: nitrate reductase (Nar), nitrite reductase (Nir), nitric oxide reductase (Nor) and nitrous oxide reductase (Nos). The key enzyme is Nos, which is a soluble protein with a weak ability to compete for electrons. When the electron donor is insufficient in the environment, the activity of Nos is inhibited due to the competition of other reductases, leading to the accumulation of N2O; when the electron donor is sufficient in the environment, Nos resumes activity, and N2O can be smoothly converted into N2, thereby reducing N2 The amount of release. The activity of denitrification reductase is affected by the external environment, the reaction products of each stage and the regulation and control of chemical substances, and its activity and concentration directly determine the final product of the denitrification process[30].
At present, there are two possibilities for the release of N2O in the denitrification process as follows: (1) Due to adverse environmental conditions, the Nos activity during the reaction of denitrifying bacteria is lost or reduced, so that the N2O produced in the third stage cannot be further reduced. Cause N2O to accumulate and escape from the water body. (2) Some special denitrifying bacteria do not have Nos system, and the final product is only N2O. Therefore, in the sewage treatment system, if the gene sequence containing Nos is isolated to make this type of denitrifying bacteria a dominant flora, it will help reduce the amount of N2O released during the denitrification process.

2.2 Factors affecting N_2O release and pollutant removal

The research results have confirmed that N2O will be produced in the nitrification and denitrification reactions in the biological denitrification process of sewage[31]. In recent years, researchers from various countries have carried out studies on the effects of different factors on the release of N2O, with a view to controlling N2O emissions under the premise of ensuring high pollutant removal rates by optimizing the best influencing factors.

In the biological treatment of sewage, the release of N2O in different treatment processes is different. Studies have shown that the N2O release of the attached growth system is different from that of the suspended growth system. In the attached growth system, the bacteria that can control the production of N2O can be fixed on the carrier or filler. Therefore, the attached growth system is better than the suspended growth system. It is easier to control the production of N2O. This is mainly due to the difference in the microbial community structure of the attached growth system and the suspended growth system[32]. However, under certain conditions, the N2O release amount in the suspended growth system is also low. Therefore, different operating conditions of the same treatment process will also cause The difference in N2O release. The factors that affect the release of N2O and the removal

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of pollutants in the same process of biological denitrification of sewage are mainly divided into two aspects: operating conditions and sewage water quality.

2.2.1 Operating conditions

In the same treatment process, such as SBR process, its water inlet method, aeration method and operating conditions will affect its treatment effect and the release of N2O.

The water inlet method can be divided into instantaneous water inlet and staged water inlet. The staged water inlet activated sludge process is a new type of biological denitrification process newly developed in recent years and gradually being widely studied, which is different from the traditional A/O sewage biological denitrification process. Process, segmented water does not need to set up a reflux system, which saves energy and reduces consumption, and can reduce infrastructure investment. In addition, the staged water inflow keeps the organic matter in the reactor at a low concentration level. In a reactor where carbon oxidation and nitrification are carried out at the same time, heterotrophic decarburization bacteria also allow competition between autotrophic nitrifying bacteria. Therefore, the low level of organic matter maintained by the staged inflow is beneficial to the growth of nitrifying bacteria and improves the denitrification capacity of the reactor. Park et al. found that for the SBR reactor, changing the water inlet method affects the release of N2O[33]. The amount of NCO released in the aerobic section accounts for 3.78% of the TN in the inlet water, while it is only 1.95% in the anaerobic section. Aeration methods can be divided into Continuous aeration and intermittent aeration. The former is simple to operate but high energy consumption, and the latter saves energy and reduces consumption, which is conducive to the denitrification of aerobic denitrifying bacteria and heterotrophic nitrifying bacteria and the accumulation and storage of PHB[33].

The gas realizes the alternating process of frequent anoxic denitrification/aerobic nitrification, which is beneficial to the realization of the denitrification process. However, to obtain the ideal denitrification effect, a reasonable time distribution ratio must be controlled. Uchida et al. [studied the intermittent aeration process and pointed out that the optimal aeration time ratio of 0.70.0.75 would achieve the best denitrification effect. Combined with the stepwise water inlet, the water inlet point is controlled in the anoxic section, which can provide sufficient carbon source for denitrification, which is beneficial to the removal of TN. At present, there are few studies on the single-stage and multi-stage hypoxic/aerobic N2O release.

The same treatment process, under the same operating conditions, and different operating modes will also affect the denitrification effect and N2O release of the sewage biological denitrification system[34].

2.2.2 Sewage water quality

The ratio of carbon to nitrogen in the influent has a great influence on the release of N2O during the biological denitrification process of sewage, and is one of the main factors affecting the removal of pollutants. The ratio of influent carbon to nitrogen directly affects the degree of denitrification of the system. Since the denitrification process requires an organic carbon source to provide electron donors, the higher the ratio of carbon to nitrogen in influent, the better the effect of denitrification and denitrification. When the external carbon source is insufficient, the amount of N2O released increases, which is due to the accumulation of NO2--N by denitrifying bacteria using their own endogenous carbon for denitrification under the condition of low influent carbon to nitrogen ratio.

Kishida et al. found that the carbon-to-nitrogen ratio in the pig wastewater treatment system has no effect on the production of N2O during the aerobic nitrification process, while the carbon-to-nitrogen ratio has a significant impact on the release of N2O during the denitrification process. In the denitrification process, when BODS/N is 2.6, the amount of N2O produced is about 270 times that of BODS/N of 4.5. Hanaki et al. studied the denitrification process with sodium acetate as the carbon source and nitrate as the nitrogen source, and proved that the low carbon to nitrogen ratio is more prone to N2O accumulation. Park et al. found that in hypoxia, the average release rate of N2O decreases as the carbon to nitrogen ratio increases. Hwang et al. found that in the process of denitrification, when the carbon to nitrogen ratio is reduced to 3, no N2O is released. When the carbon to nitrogen

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ratio is reduced to 2, N2O with a mass concentration of 130 mg/L is produced. The reason is carbon Insufficient source leads to incomplete denitrification, so N2O becomes the final product[35-38]. Wu et al. found that in the process of treating domestic sewage in constructed wetlands, when the carbon-to-nitrogen ratio is 5, the smallest N2O release and denitrification effects can be obtained. In many large and medium-sized cities in my country, the carbon and nitrogen of domestic sewage is relatively low, and in many northern cities, the carbon-nitrogen ratio changes greatly within a year due to seasonal changes. Therefore, the study of the influence of the influent carbon-nitrogen ratio on the release of NCO has an impact on the actual urban life. The treatment of sewage is of great significance[39].

III. The Impact of the Influent Carbon-Nitrogen Ratio on the Removal of Pollutants and the Release of N_2o in the Sewage Biological Denitrification System

In the biological denitrification process of sewage, the carbon-nitrogen ratio, DO concentration, pH and temperature can affect the pollutant removal effect and N2O production. The carbon-nitrogen ratio is the main factor affecting the biological nitrogen removal system of sewage. Too low a carbon-to-nitrogen ratio will hinder the progress of denitrification, and cause simultaneous nitrification and denitrification in the mixed system to be inhibited, affecting the total nitrogen removal of the entire system; too high a carbon-to-nitrogen ratio will not only reduce the rate of nitrification and denitrification, but also cause Waste of resources. The low COD of domestic sewage and high ammonia nitrogen concentration in our country are important reasons for the abnormal operation of many newly-built sewage plants in many cities and towns. However, there are many studies on the effect of carbon to nitrogen ratio on the removal of pollutants in the nitrification and denitrification process, and there are few studies on the combination of N2O release[40].

Therefore, the experiment took anoxic-aerobic SBR reactors with different influent carbon-nitrogen ratios as the research object, studied the influence of the influent carbon-nitrogen ratio on the N2O release of the sewage biological denitrification system, and investigated the different influents. Under the carbon-nitrogen ratio, the removal of COD and phosphorus, and the transfer of nitrogen, preliminary discussion of the reaction mechanism, in order to achieve the purpose of energy saving and consumption reduction.

3.1 Test device

The laboratory-scale SBR reactor device used in the experiment is shown in Figure 2-1. The reactor is made of plexiglass and has a cylindrical shape with an inner diameter of 150mm, a height of 450mm, and an effective volume of 6L. The water in and out of the reactor is controlled by a time relay, a peristaltic pump and a solenoid valve; a sticky sand block aeration head is installed at the bottom of the reactor, and the gas flow is controlled by a rotameter, and the aeration volume is set to 4; through the bottom of the reactor The magnetic stirrer maintains the sludge suspension and the uniformity of the system; a heating rod is placed inside the reactor, and the temperature is controlled at 24±2℃; during the operation of the system, part of the sludge mixture is discharged at the end of the aerobic section every day to control the MLSS in About 3000 m/L[41-43].

3.2 Test water quality and inoculation sludge

The test uses manual water distribution, with 3.5L water intake per cycle. Because different carbon sources are used as electron donors, the reaction conditions are different, so glucose and sodium acetate are used as mixed carbon sources; chlorination is used as the nitrogen source, and the ammonia nitrogen concentration is about 60 mg/L. Dipotassium hydrogen phosphate and dihydrogen phosphate Potassium, magnesium sulfate, calcium chloride, ferrous sulfate, etc. are trace elements. To study the N20 release, COD and phosphorus removal, and nitrogen transfer of the sewage biological nitrogen removal system under different carbon-nitrogen ratio gradients (1.2, 3.5, 6.8, 9.2, 12.9).

3.3 Collection and determination of gaseous N_20

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At the gas outlet of the overall closed SBR reactor, use a portable gas sampling pump (02L-D, Dalian Delin Gas Packaging Co., Ltd.), and use an air bag (Dalian Delin Gas Packaging Co., Ltd.) to collect the upper space of the closed reactor. gas. Samples were collected at an interval of 10 minutes, and the measurement was performed within 24 hours.

The concentration of N20 in the collected gas was measured using a gas chromatograph (SP-34) equipped with a 63N1 electron capture detector (ECD), Beijing Ruili Analytical Instrument Co., Ltd.). The gas chromatograph uses Porapak Q as the packed column material. The chromatographic conditions are: the detector temperature is 3900C, the carrier gas is high-purity nitrogen (purity>99.999%), and the flow rate is 30mL/min.

3.4 Data analysis

Data analysis is processed by Microsoft Exce12003, Origin 8.5. SPSS 11.0 and other software.

3.5 Pollution removal effect of sewage biological denitrification system under different influent carbon-nitrogen ratios

Janssen et al. believe that the key to biological nutrient removal in the BNR (Biological Nutrient Removal) system is the composition of sewage components such as C/N. The research of Wang Yayi[[s6] and Wang Xiaolian pointed out that C/N in the BNR system is the most important influencing factor for nitrogen and phosphorus removal. They conducted in-depth research on the influence of influent CIN on process nitrogen and phosphorus removal, and discussed its influence mechanism. A large number of research experiments have proved that the carbon to nitrogen ratio is the most important factor affecting nitrogen and phosphorus removal in the operation of the SBR process[44].

IV. Reduction Control of Optimized Working Conditions in Sewage Biological Denitrification System with Low Influent Carbon to Nitrogen Ratio

4.1 Biological denitrification technology is currently the most widely used sewage denitrification technology.

Biological denitrification technology uses nitrifying bacteria and denitrifying bacteria to remove nitrogen in sewage. The key to efficient denitrification of denitrifying bacteria is sufficient carbon source. It is also an important control parameter that affects the production of N2O during the denitrification process.

According to the impact test of the influent carbon-nitrogen ratio on sewage biological denitrification and N2O release, it can be known that the influent carbon-nitrogen ratio has an important impact on the pollutant removal effect and N2O release. Under the condition of low influent carbon to nitrogen ratio, the effect of pollutant removal in anoxic-aerobic SBR sewage biological denitrification system is poor, but the amount of N2O released is less. As the influent carbon to nitrogen ratio increases, pollutants are removed The rate increases but the amount of N2O released increases[45]. The release of N2O in the sewage biological denitrification system cannot be ignored. Therefore, under the premise of ensuring the removal effect, it is of great significance to study the N2O reduction control of the sewage biological denitrification system.

In China, COD, BOD: low phenomenon is common in many urban sewage, and the problem of insufficient carbon source, especially in southern cities, this situation is more common. Due to the low carbon-to-nitrogen ratio in sewage and insufficient carbon source supply, the denitrification reaction conditions of many conventional biological denitrification processes cannot be met, resulting in poor pollutant removal effects. Research results at home and abroad show that when the influent ClP<20 and C/N<6, all the current biological nitrogen and phosphorus removal processes for sewage will be difficult to achieve simultaneous nitrogen and phosphorus

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removal due to low carbon sources. The development of simple, high-efficiency, energy-saving and sustainable new urban sewage treatment technology is the development trend of modern urban sewage treatment. Therefore, considering the relatively low carbon and nitrogen of urban sewage in China, especially in southern cities, research on sewage biological denitrification systems with low influent carbon to nitrogen ratios, optimize working conditions, and achieve good pollutant discharge effects without increasing N2O release The amount is of great significance.

4.2 Pollution removal effect of sewage biological denitrification system under different operating conditions

Under different operating conditions, the removal of pollutants in the biological denitrification process of sewage is as follows:

There is no significant difference in the removal rate of COD and ammonia nitrogen in the three reactors under different operating conditions, and the removal rate of ammonia nitrogen in the 2# reactor is slightly lower. The final effluent COD can reach 20-27 mg/L, and the effluent ammonia nitrogen can reach. -0.5 mg/L. The ammonia nitrogen removal of 2# reactor is slightly lower (97.95%) than that of 1# and 3# reactors. This is because the addition of carbon source makes the carbon-containing organic matter in the sludge flocs relatively increase, which promotes the growth of heterotrophic bacteria and autotrophic The growth of type nitrifying bacteria is inhibited.

In the three reactors with different operating conditions, the removal effect of total nitrogen is very different. The removal rates of total nitrogen are: 53.24%, 70.38%, 56.9%. The removal effect of total nitrogen in the 2# reactor is significantly better than that in the 1# and 3# reactors. This is because the denitrifying bacteria are heterotrophic bacteria and require organic The carbon source acts as an electron donor, and the addition of a carbon source allows the denitrifying bacteria in the sludge in the reactor to obtain more sufficient carbon source to reduce more NOx-N to N2, thereby increasing the removal rate of total nitrogen[46].

In the three reactors with different operating conditions, the removal effect of total phosphorus is very different. The removal rates of total phosphorus were 12.54%, 94.51% and 9.55% respectively. The basic principle of biological phosphorus removal is to use the "luxury phosphorus uptake" capability of phosphorus accumulating organisms (PAO). In anoxic-aerobic process, PAO absorbs low-molecular organic matter in an oxygen-deficient environment and releases phosphorus through hydrolysis to provide the necessary energy. After entering the aerobic environment, it oxidizes and decomposes the low-molecular organic matter absorbed by the phosphorus-accumulating bacteria, and provides energy to absorb excess phosphorus from the sewage, and stores the phosphorus in the form of polyphosphate in the bacteria body to form high-phosphorus sludge and discharge the remaining The sludge finally gets a good dephosphorization effect. Since the external carbon source in the 2# reactor provides a sufficient carbon source, it will not become a limiting factor for PAO anaerobic phosphorus release in the anoxic section, so it has a higher removal rate.

4.3 Nitrogen conversion and N20 release in a typical cycle in the system under different operating conditions

The nitrogen concentration in the hypoxic period did not change much. The ammonia nitrogen was diluted from 63.08 mg}L-' to 30.38 mg/L after the water intake, and it decreased slightly at the end of the hypoxic period, which was due to the assimilation of microorganisms. Ammonia nitrogen in the aerobic section is gradually degraded due to aerobic nitrification.

There were two peaks of nitrous nitrogen in both anoxic and aerobic periods. After water intake, the concentration of nitrous nitrogen rose to a certain extent and then decreased after peaking. This is because the reduction rate of nitrite nitrogen and the reduction rate of nitrite nitrogen are different during the denitrification process in the anoxic section. Studies have pointed out that when the influent carbon and nitrogen are relatively low or when

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sodium acetate is used as the carbon source, the reduction rate of nitrate nitrogen is greater than the reduction rate of nitrous nitrogen, which ultimately results in the accumulation of nitrous nitrogen. After entering the aerobic section, free ammonia (CFA) inhibits the smooth progress of the nitrification reaction, resulting in the accumulation of NOD-N[47].

V. Conclusions and Prospects

5.1 The effect of different influent carbon-nitrogen ratios on nitrogen conversion in sewage biological nitrogen removal system

(1) The COD removal rate in the sewage biological denitrification system is not greatly affected by the influent carbon to nitrogen ratio, and the effluent COD concentration is 21-29 mg/L. When the carbon-nitrogen ratio of the influent is 1.2, denitrification is inhibited due to insufficient carbon source supply and cannot provide alkalinity for the subsequent aerobic nitrification, resulting in the removal rate of ammonia nitrogen only 76.5%. When the carbon-nitrogen ratio of the influent is greater than 1.2, the ammonia nitrogen removal rate Both can reach more than 95%. As the ratio of carbon to nitrogen in the influent increases, the removal rate of total nitrogen and total phosphorus gradually increases.

(2) In the anoxic stage, as the ratio of carbon to nitrogen in the influent increases, the removal of nitrogen is mainly through the assimilation of microorganisms. In the aerobic section, as the ammonia nitrogen is oxidized, nitrate nitrogen gradually accumulates, but due to the low sludge age under the high influent carbon to nitrogen ratio, the abundance of nitrifying bacteria is small, so that the ammonia oxidation rate gradually decreases as the influent carbon to nitrogen ratio increases . As the ratio of carbon to nitrogen in the influent increases, the concentration of nitrite nitrogen gradually decreases due to the competition between nitrate nitrogen reductase and nitrite nitrogen reductase during the simultaneous nitrification and denitrification process.

5.2 The impact of different influent carbon-nitrogen ratios on the release of N_2O in the sewage biological denitrification system

(1) In sewage biological denitrification systems with different influent carbon-nitrogen ratios, the release of N2O during the cycle is mainly concentrated in the aerobic section, and there is almost no N2O release in the anoxic section. In the aerobic section, there is a good positive correlation between the N2O release rate and the nitrite concentration, so the release of N2O in the aerobic section mainly comes from the denitrification process. On the one hand, it is through the denitrification of nitrifying bacteria, and on the other hand, it is through the simultaneous nitrification and denitrification of the aerobic stage.

(2) Influent carbon-nitrogen ratio has an important influence on the release of N2O. In the aerobic section, when the influent carbon to nitrogen ratio is lower than 6.8, the amount of N2O released is less. Under the condition of low influent carbon to nitrogen ratio, N2O is mainly produced by endogenous denitrification. When the carbon-nitrogen ratio is higher than 6.8, the aerobic stage N2O release is the largest, and the amount of N2O released decreases with the increase of the influent carbon-nitrogen ratio. When the influent carbon to nitrogen ratio is b.8, the N2O release is the largest.

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